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CALCULATIONS OF CONCENTRIC CYLINDRICAL FOIL LINER IMPLOSIONS TO PRODUCE COLLAPSING RADIATION CAVITIES

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13. ABSTRACT *(Maximum 200 Words)*
This report presents the concept and results of calculations of the use of colliding concentric cylindrical foil liners to produce collapsing radiation cavities. The concept is to use a magnetic pressure driven foil plasma liner to implode on a second interior liner at several tens of centimeters per microsecond. The outer liner collision with the inner liner converts the implosion kinetic energy to thermal energy, with temperatures of 100 to 200 electron volts possible. The calculations were done with a Langrangian one-dimensional Magnetohydrodynamic (MHD) code and multigroup radiation treatment.

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Calculations of concentric cylindrical foil liner implosions to produce collapsing radiation cavities

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In 1978-1980, we computationally simulated implosions of cylindrical foil plasma liners with an initially stationary and unvaporized inner foil liner. We initially did this to explore a scheme for sharpening the risetime of the radiation pulse that results from the assembly of a single liner on the axis of symmetry. We found that for comparable mass Al liners, with implosion velocities of several 10s of cm/usec, inner liner radius ~1 cm, and implosion kinetic energies of several 100 kJ per centimeter of axial dimension, we computationally obtained ~80 eV radiation temperatures inside the inner liner, right after collision of the outer and inner liners. We realized the significance of this and pursued a computational study of schemes to increase this temperature. That is, we realized that this could be an efficient approach to producing a high temperature radiation cavity, or hohlraum, of interest for Inertial Confinement Fusion (ICF).

We did these concentric liner simulations in Lagrangian 1D - radiation hydrodynamic treatment, with multigroup radiation treatment, with an assumed thickness of the outer liner consistent with empirical information on capacitor driven foil liner implosions,[1] and consistent with both analytic estimates and 2D-MHD simulations of the thickening of such liners due to instability growth.[2] We did some simulations with a Gaussian profile of the outer liner density vs radius, with FWHM ~ 1 cm, and the outer liner initially ~1 cm outside the inner liner, with an initial velocity of some 10s cm/usec. We did larger numbers of analagous simulations with simpler rectangular density vs radius profiles. We varied the liner materials, mass per unit length (and mass ratio of outer to inner liner), initial radii, and the outer liner's initial FWHM and initial (inward) velocity. The concept illustration is shown in Figure 1.

Some of these simulation results are summarized in Figures 2 through 11. They indicate, for example, that one can obtain ~200 eV hohlraums by means of Au plasma liners imploding on 1 cm radius Al foil inner liners with implosion velocity of 50 cm/usec and kinetic energy of 3 MJ per centimeter of length. More generally, these simulations indicate that the radiation temperature is optimized by using an outer liner that will have

an optical depth of 10 to 100, and an inner liner that will have an optical depth of ~1, when the 2 liners have collided.

The simulations were guided by, and gave results consistent with, some analytic considerations, which we briefly discuss here.

The velocity of the outer foil is estimated by the desired temperature:

$$(1/4)\,(1/2)\,mv^2 = mc_vT$$

where m,v,c_v,T are foil mass (per unit length), foil velocity (inward), specific heat, and desired material temperature after collision. Equal mass for inner and outer foils is assumed for this expression. The inner liner temperature after collision is maximized by equal inner and outer liner mass. For an ideal gas with Z/A=1/2,

$$v = 24\,(T_{100})^{1/2}\ \mathrm{cm/us}$$

where T_{100} is temperature in units of 100 eV. This overestimates the temperature that is predicted by typical simulations, but is a useful guide.

The choice of initial radius of the inner foil can be estimated by the desired duration of the hohlraum between foil collisions and arrival of the foils on axis. One also wants that initial radius to be a few times the radius of an ICF target. Such considerations lead to an initial inner foil radius of ~0.5 to 1 cm. The choice of foil mass and materials is related to the desirability of optical depths being ~1 for the inner foil, so that it radiates efficiently, and large for the outer liner, to avoid radiation losses.

We did subsequent simulations (1980-1982) for variants of this scheme in which the inner foil is replaced by a foam (low density) shell or a solid foam cylinder. These results show a still higher radiation temperatures, for useful durations (several nanoseconds) prior to the outer liner reaching the axis.

These schemes were independently developed by Los Alamos National Laboratory and by the Angara 5 research team (Smirnov et al.). The Angara 5 work, which included experimental attempts that produced results in the 60 to 70 eV range, was first openly reported during a post conference tour following the Beams'90 conference.

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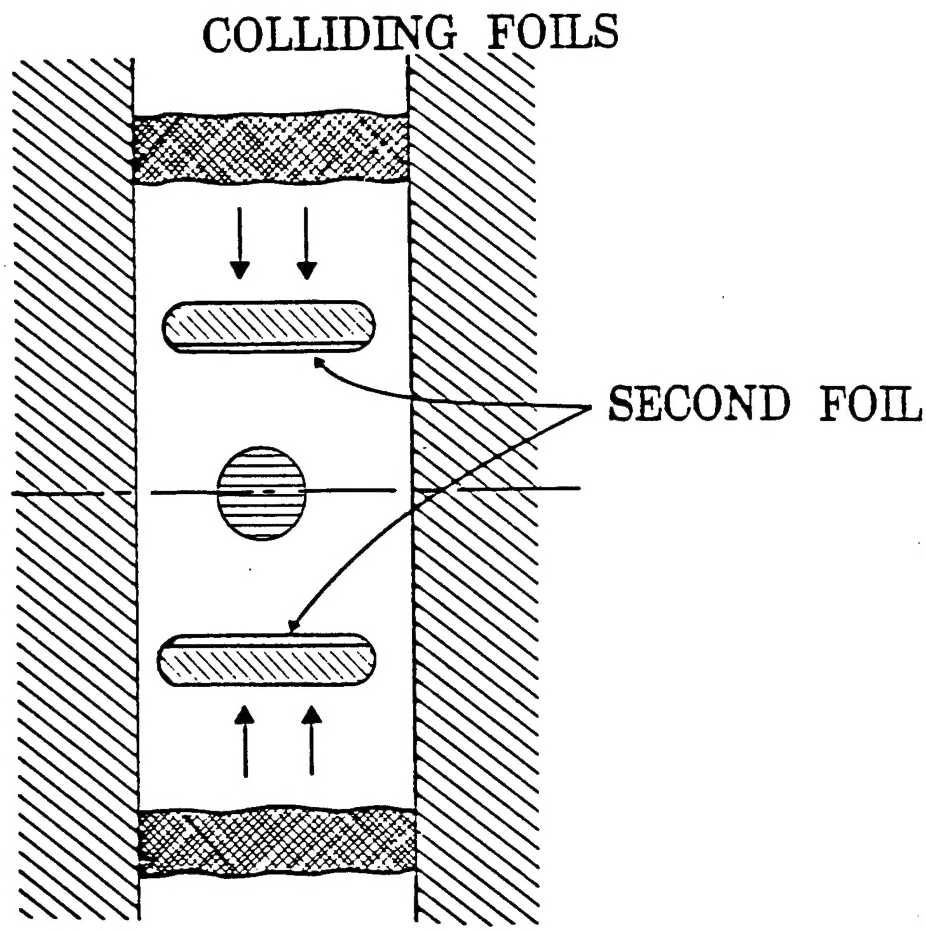
1. W.L. Baker, M.C. Clark, J.H. Degnan, G.F. Kiuttu, C.R. McClenahan, and R.E. Reinovsky, J. Appl. Phys. 49, 4694 (1978)
2. T.W. Hussey, N.F. Roderick, and D.A. Kloc, J. Appl. Phys. 52, 1352 (1980)



- OUTER FOIL STAGNATES ON INNER FOIL, CONVERTING KINETIC ENERGY TO INTERNAL ENERGY
- OUTER FOIL MATERIAL CHOSEN TO HAVE HIGH OPACITY, CONTAIN RADIATION

Figure 1. Illustration of concept for using colliding concentric cylindrical foils to produce collapsing radiation cavity.

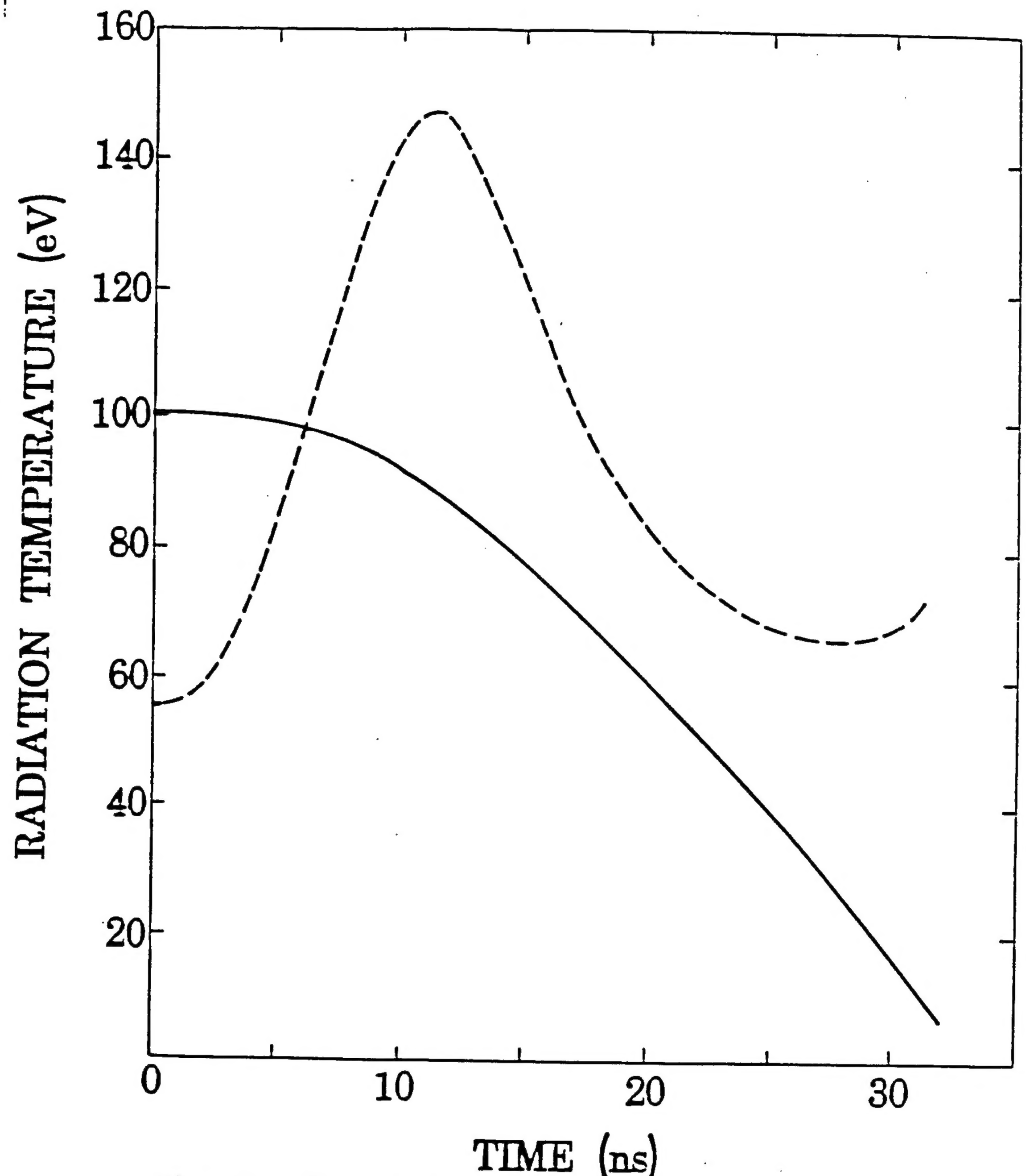


Figure 2. The dashed line is radiation temperature versus time for colliding foils with the following initial parameters:

Mass of outer foil = 0.025 g

Velocity of outer foil = 4×10^7 cm/s

Mass ratio = 1

Density of inner (outer) foil = 0.01 (0.01) gm/cm^3

Optical depth through inner (outer) foil = 1 (100)

Radius of inner foil = 1 cm

The solid line is the inner radius of the inner foil versus time. The initial radius is one cm.

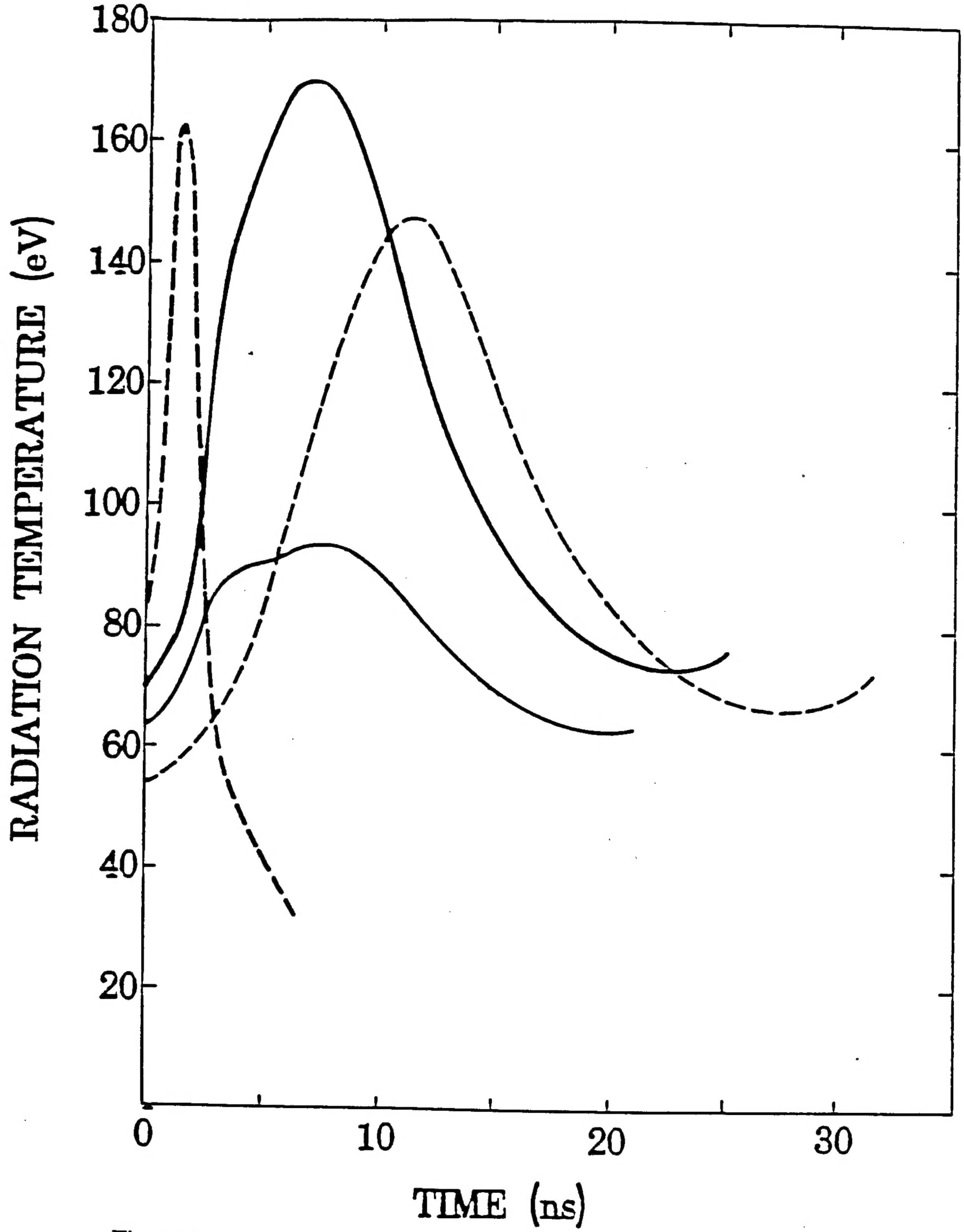


Figure 3. Radiation temperature versus time for four models. The dashed line on the right is the same as in Figure 2. The dashed line to the left represents an inner (outer) density of 0.1 (0.1) gm/cm^3. The upper solid line represents a density of 0.01 (0.1) gm/cm^3. The lower solid line represents a density of 0.1 (0.01) gm/cm^3.

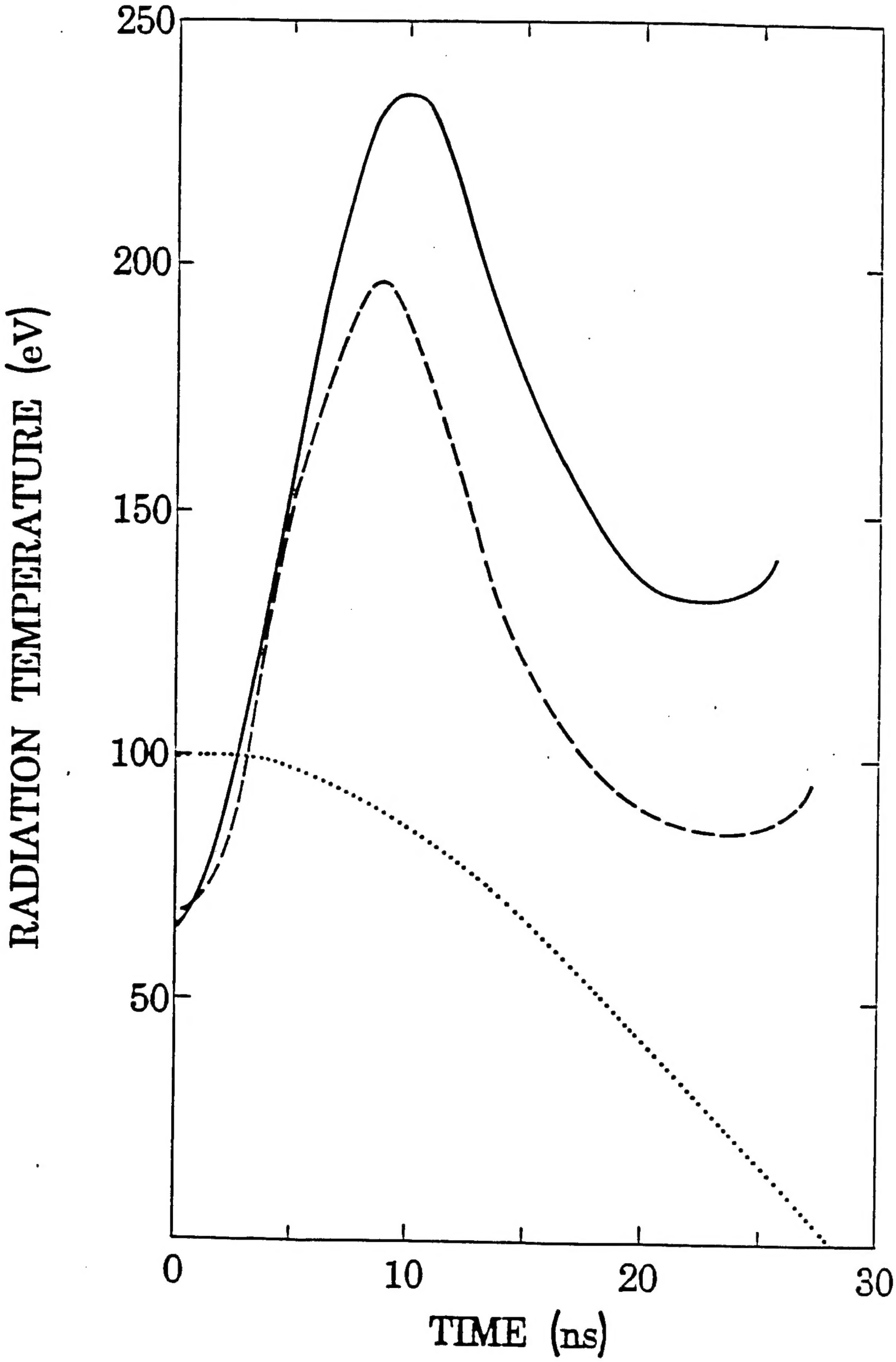


Figure 4. Radiation temperature versus time for models with outer foil velocity of 5.0 x 10^7 cm/s. The solid (dashed) line represents an outer optical depth of 100 (10). The dotted line is the radius of the inner boundary. The initial radius is one cm.

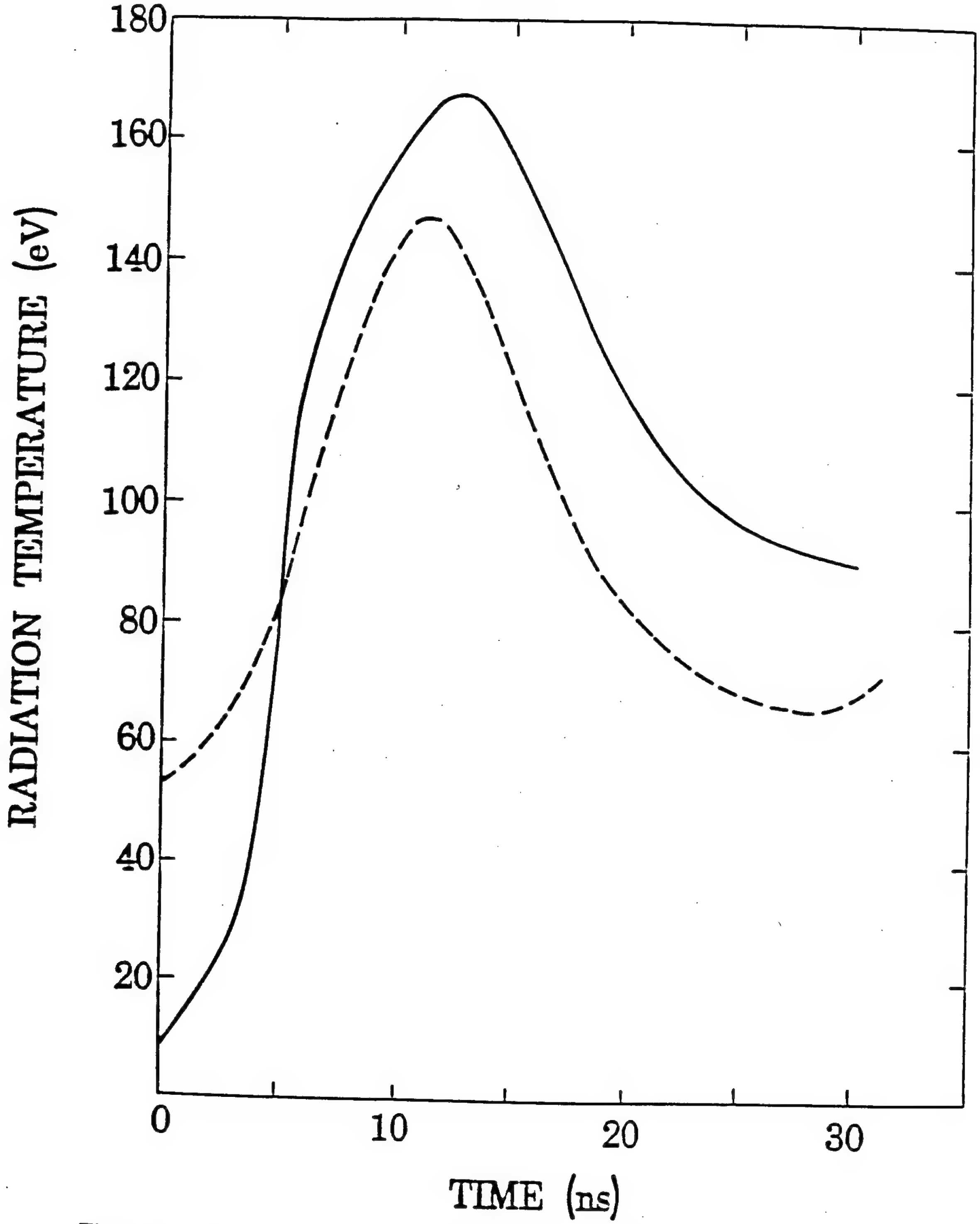


Figure 5. The dashed line is the same as in Figure 2. The solid line represents a collision of an outer gold foil onto a beryllium foil.

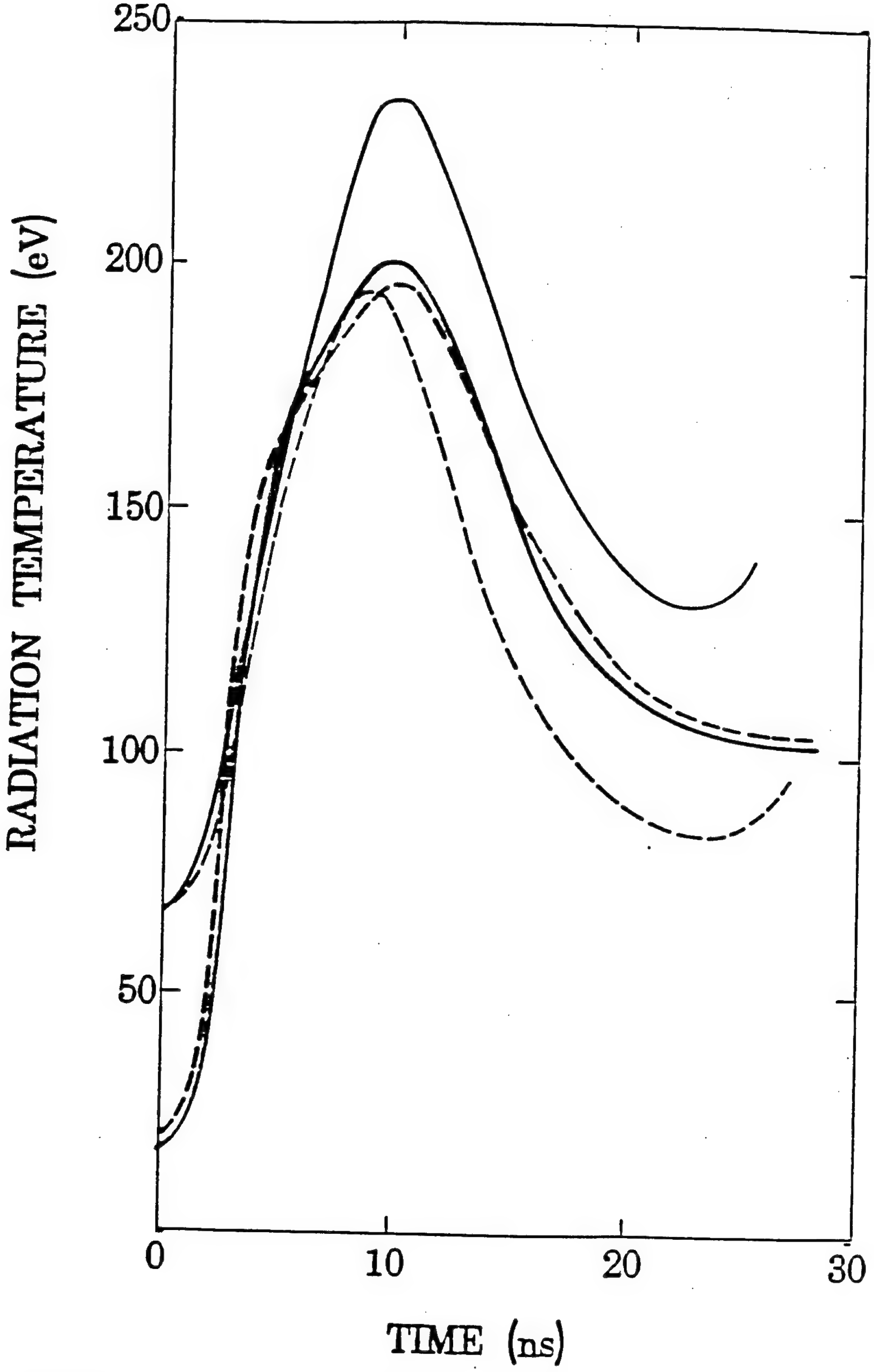


Figure 6. The upper solid and lower dashed curves are the same as in Figure 4. The other solid and dashed curves represent collisions of a gold foil onto an aluminum foil and onto a beryllium foil respectively.

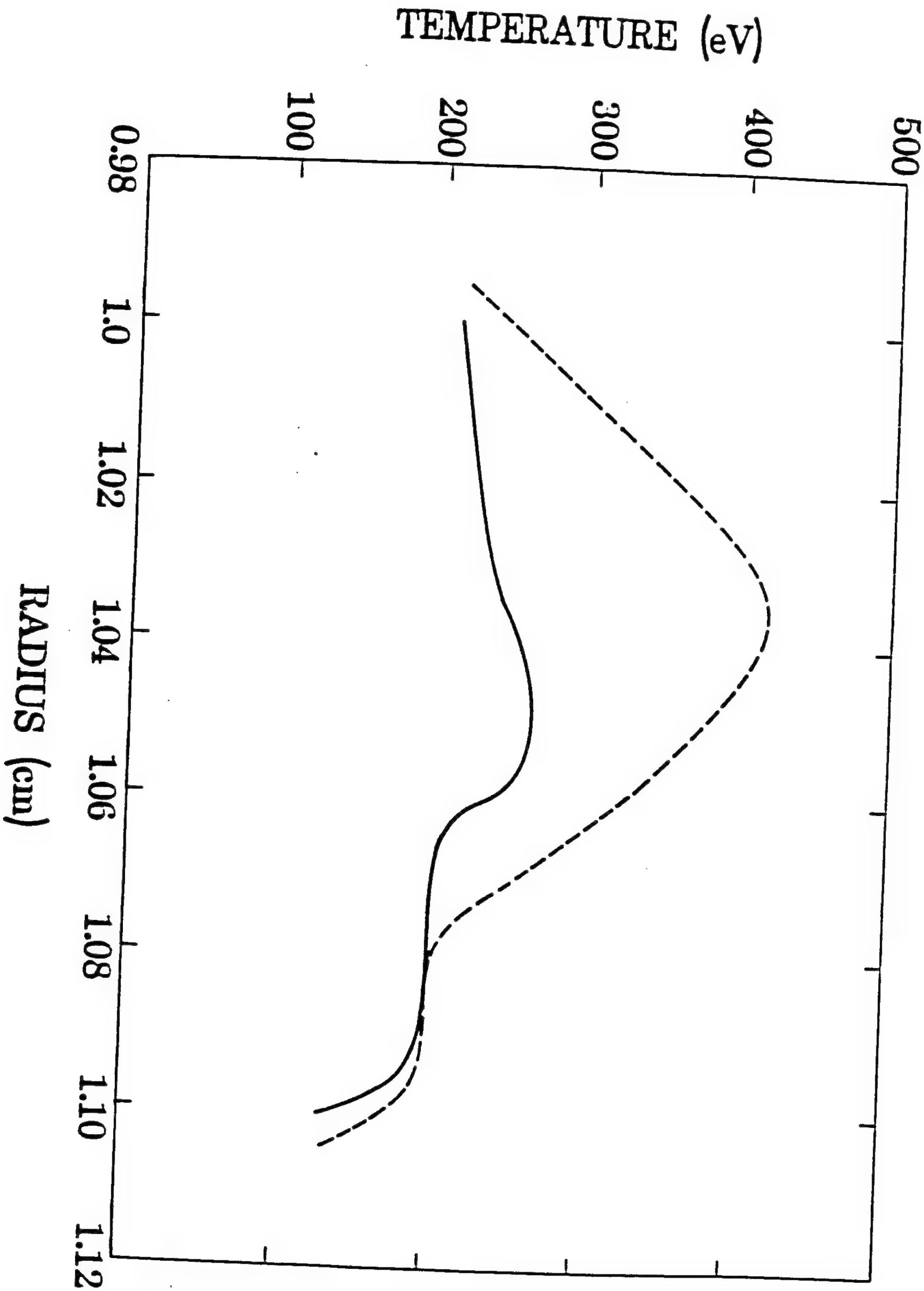


Figure 7. Electron temperature versus radius for the collision of the gold foil onto the beryllium foil (dashed curve) and onto the aluminum foil (solid line).

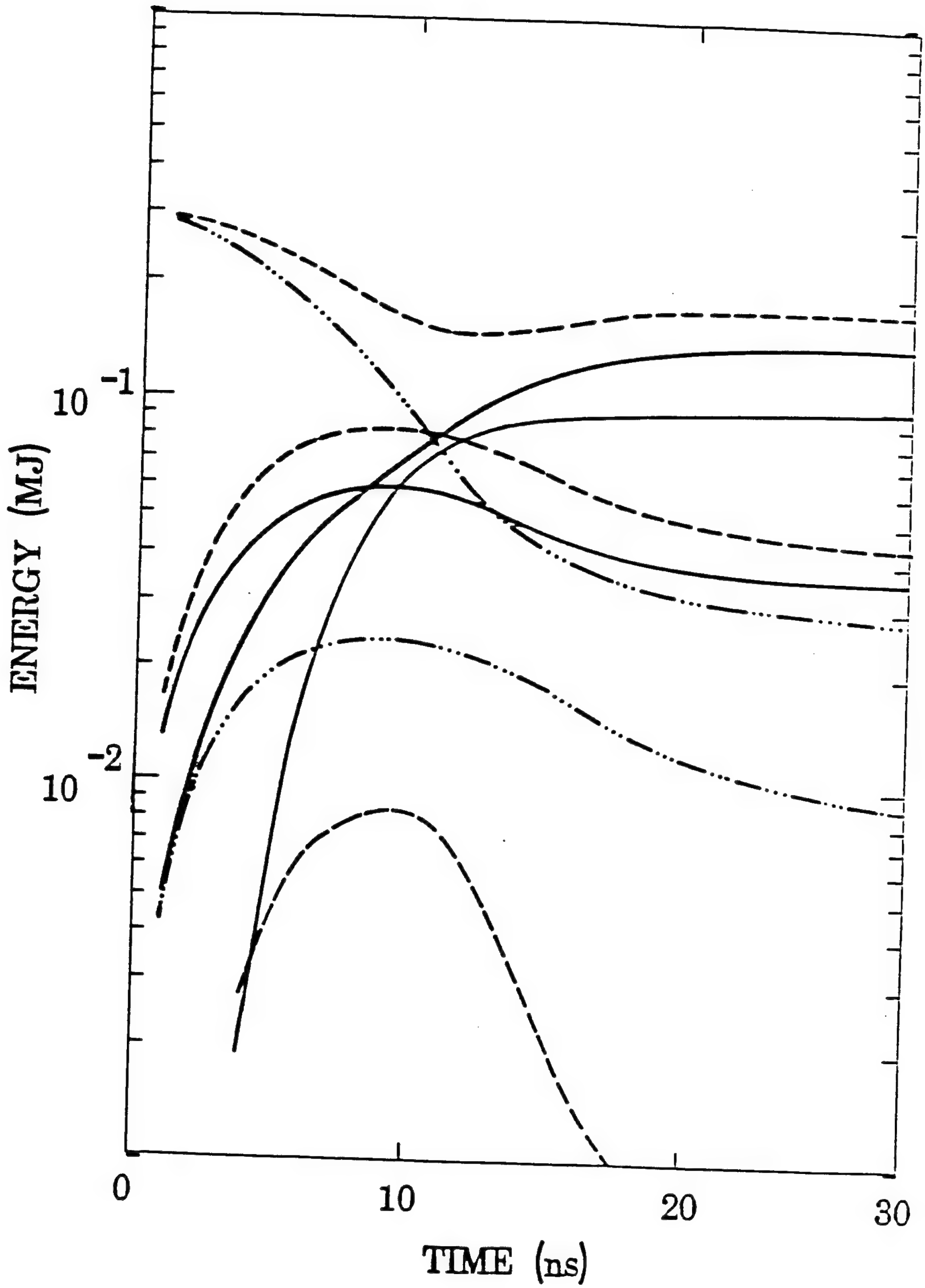


Figure 8. Kinetic energy, internal energy, radiation energy, and energy radiated versus time for the case of the gold foil colliding with the aluminum foil.

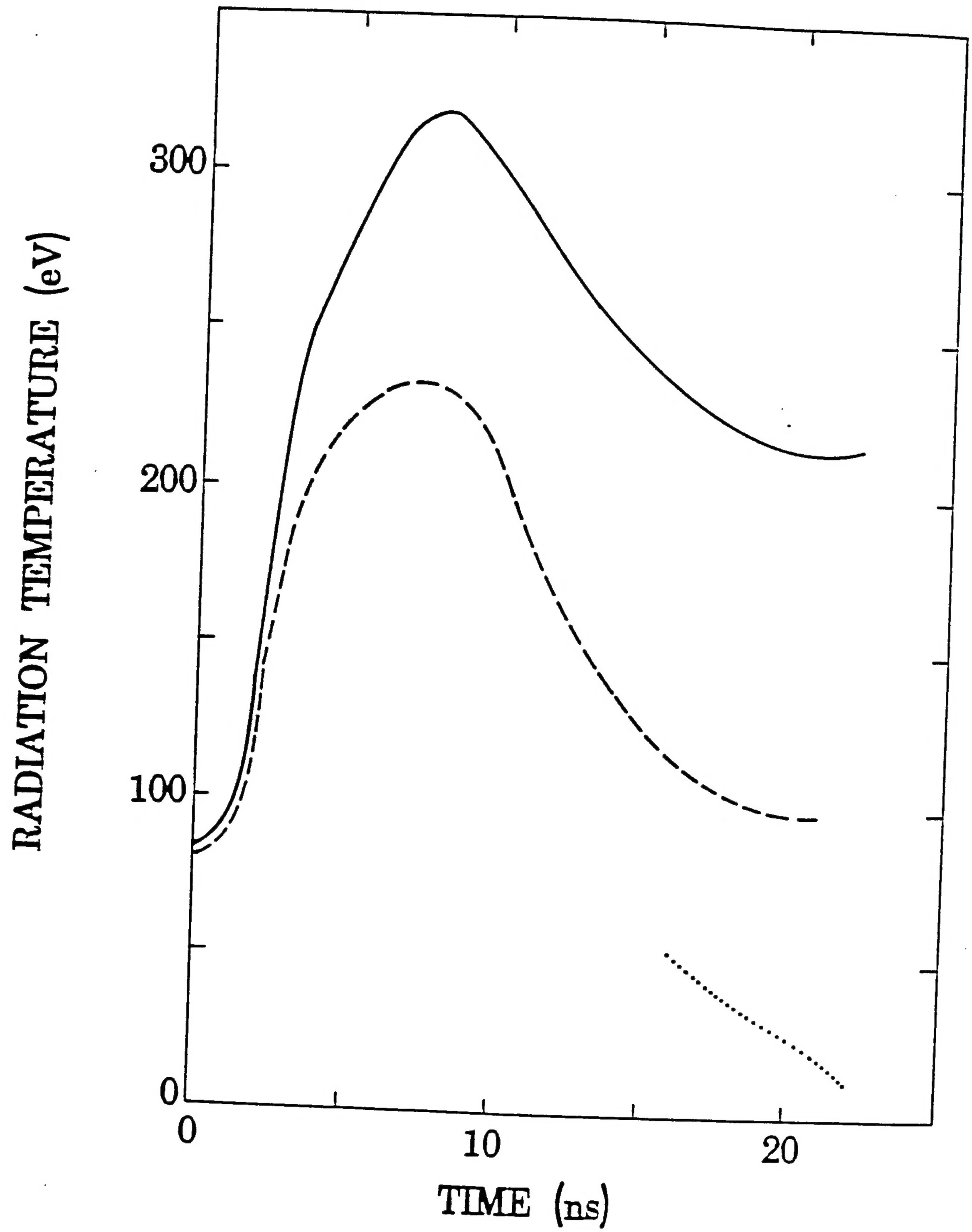


Figure 9. Radiation temperature versus time for models with outer foil velocity of 6 x 10^7 cm/s. The solid (dashed) curve has an optical depth of 100 (10).

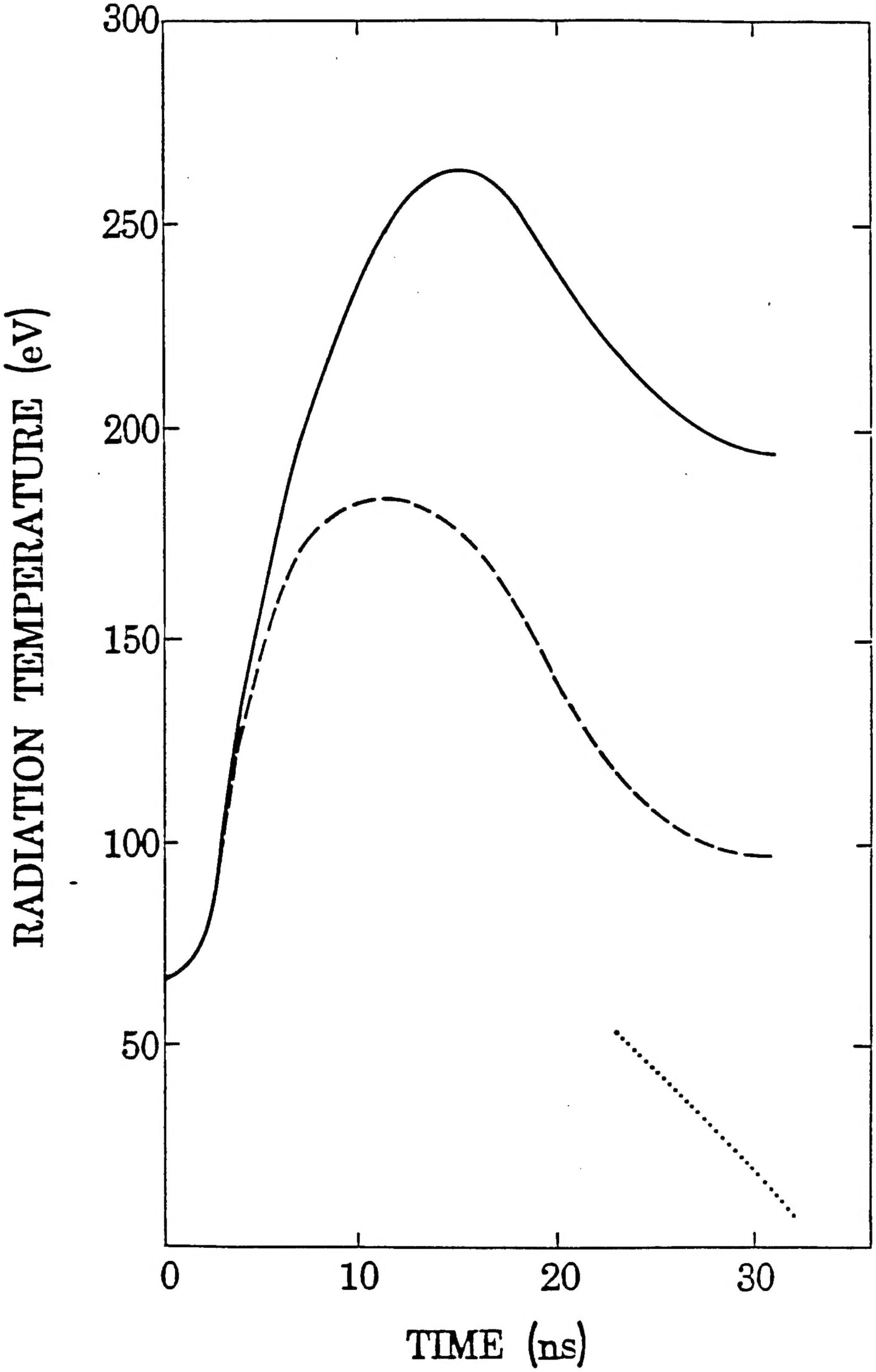


Figure 10. Radiation temperature versus time for models with outer initial velocity of 5×10^7 cm/s and an inner density of 0.005 gm/cm^3.

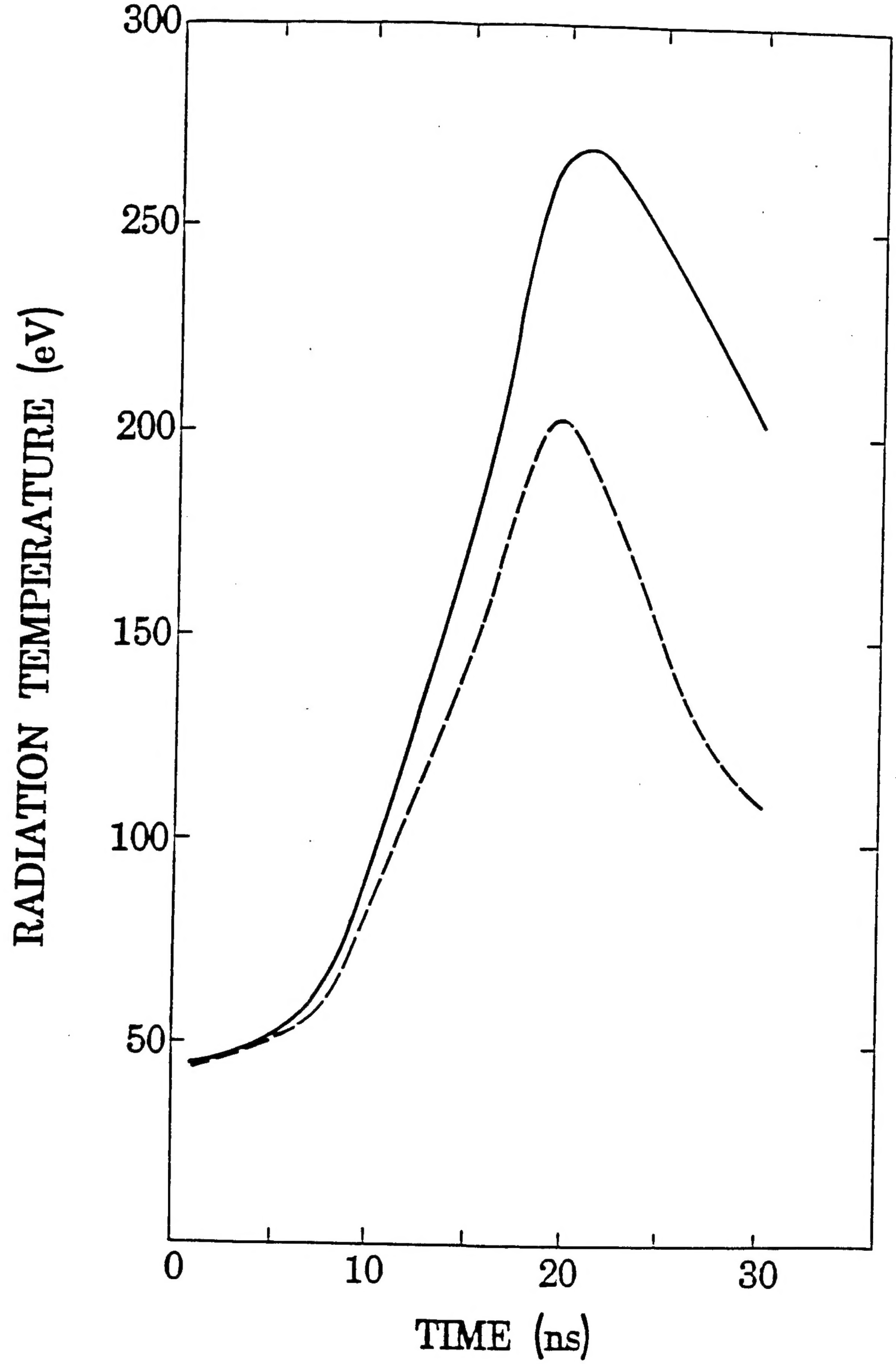


Figure 11. Radiation temperature versus time for models with Gaussian density profiles.

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